A Phase Rotated Intense Source of Muons (PRISM) for a mu-e Conversion Experiment

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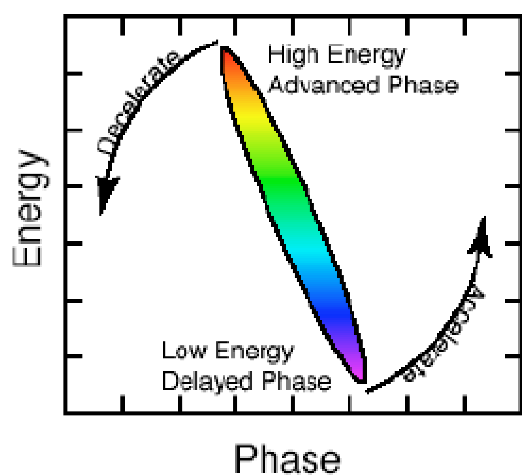
Reporting on:

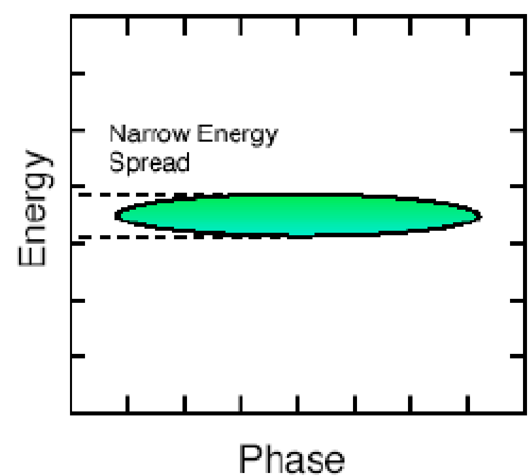
- A Phase Rotated Intense Source of Muons (PRISM) for a μ→e Conversion Experiment, SNOWMASS21-RF5_RF0-AF5_AF0_J_Pasternak-096.pdf
- Bunch Compressor for the PIP-II Linac, SNOWMASS21-AF5_AF0-RF5_RF0_Prebys-071.pdf

Introduction

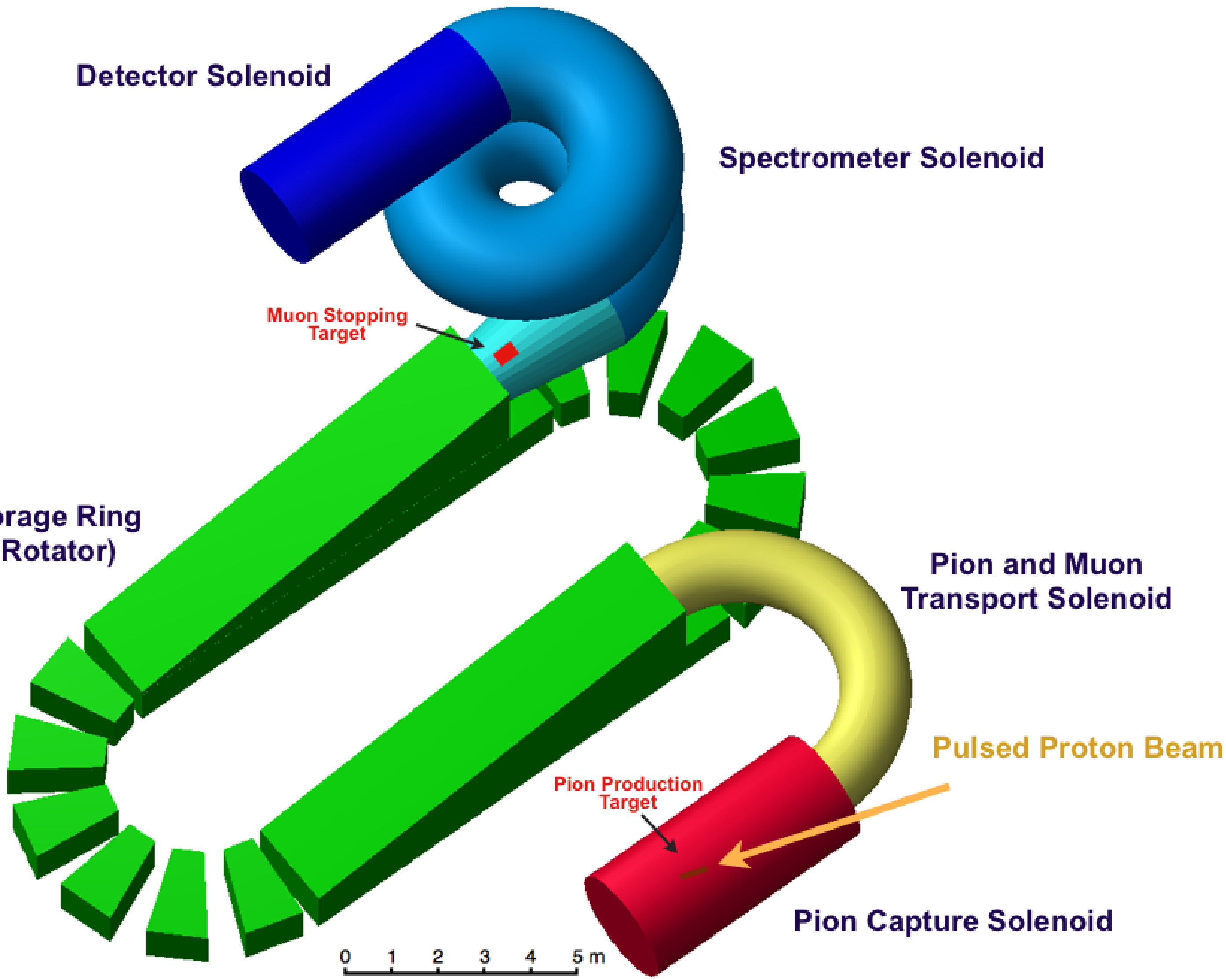
PRISM - Phase Rotated Intense Slow Muon beam

• Charge lepton flavor violation (cLFV) is strongly suppressed in the Standard Model, its detection would be a clear signal for new physics!
• The μ- + N(A,Z)→e- + N(A,Z) seems to be the best laboratory for cLFV.
• The PRISM/PRIME experiment based on was proposed(Y. Kuno, Y. Mori) for a next generation cLFV searches in order to:
 - reduce the muon beam energy spread by phase rotation,
 - purify the muon beam in the storage ring.
• PRISM requires a compressed proton bunch and high power proton beam
 - It needs a new proton driver!
• This will allow for a single event sensitivity of 3×10^{-19}





Conceptual Layout of PRISM/PRIME



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Challenges for the PRISM accelerator system

• The need for the compressed proton bunch:
- is in full synergy with the Neutrino Factory and a Muon Collider.
- puts PRISM in a position to be one of the incremental steps of the muon programme.

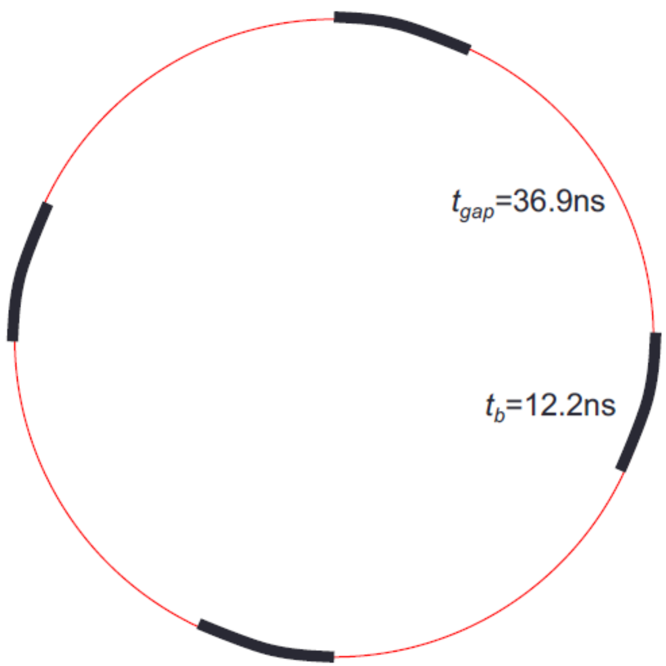
• Target and capture system:
-is in full synergy with the Neutrino Factory and a Muon Collider studies.
-requires a detailed study of the effect of the energy deposition induced by the beam

• Design of the muon beam transport from the solenoidal capture to the PRISM FFA ring.
-very different beam dynamics conditions.
-very large beam emittances and the momentum spread.

• Muon beam injection/extraction into/from the FFA ring.
-very large beam emittances and the momentum spread.
-affects the ring design in order to provide the space and the aperture.

• RF system
-large gradient at the relatively low frequency and multiple harmonics (the “sawtooth” in shape).

Realising compressed bunches using PIP-II linac



Circumference: $C = 49.7\ \text{m}$

RF Frequency: $f_{RF} = 40.62 \text{ or } 20.31\ \text{MHz}$

harmonic: $h = 8 \text{ or } 4$

Protons/bunch: $n_b = 1 \times 10^{12}$

Bunch length: $t_b = 12.2\ \text{ns}$

Fill time: $t_{fill} = 1.3\ \text{ms}$

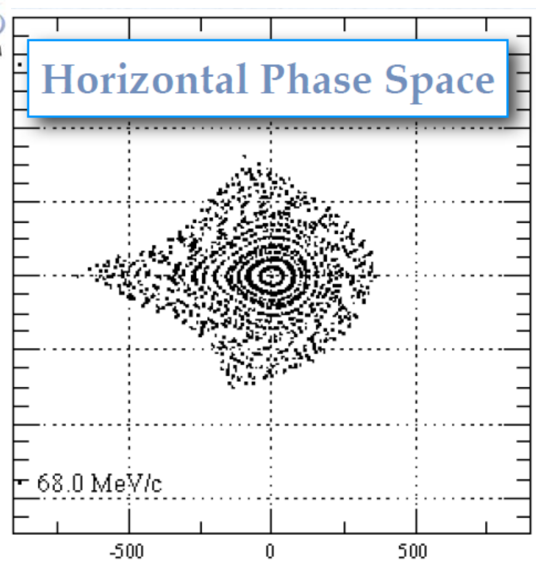
- PIP-II linac can be used to generate the compressed bunches
- Compressor ring needs to be added

- Bunch Compressor for the PIP-II Linac, SNOWMASS21-AF5_AF0-RF5_RF0_Prebys-071.pdf

R&D work in Osaka

- 10 cell DFD ring has been designed
- FFA magnet-cell has been constructed and verified.
- RF system has been tested and assembled.
- 6 cell ring was assembled and its optics was verified using α particles.
- Phase rotation was demonstrated for α particles.

Magnet for FFA cell - design



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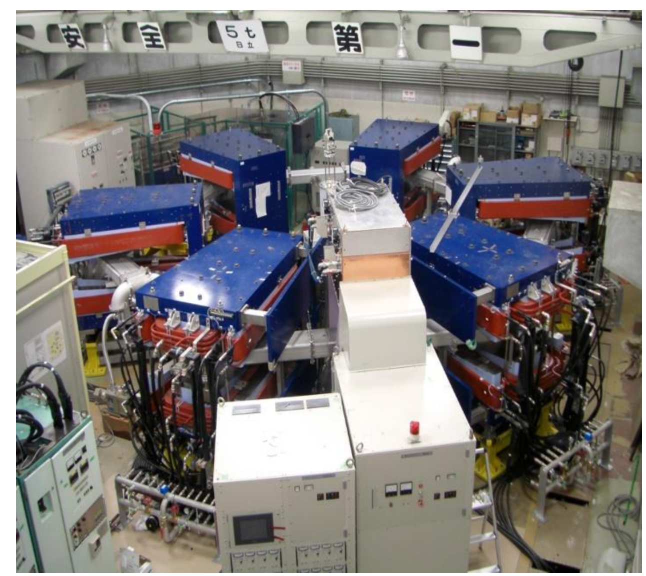
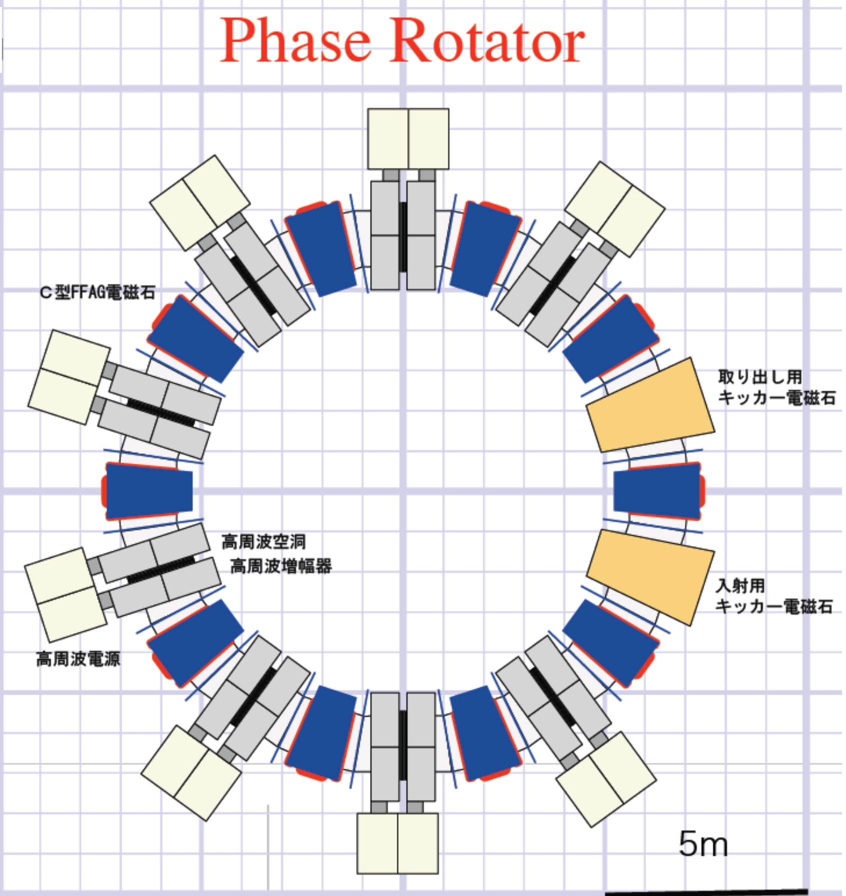
6 cell FFA ring at RCNP



First Design Parameters, A. Sato

PRISM-FFA

- N=10
- k=4.6
- F/D(BL)=6.2
- r0=6.5m for 68MeV/c
- half gap = 17cm
- mag. size 110cm @ F center
- Radial sector DFD Triplet
- $\theta_F/2$=2.2deg
- θ_D=1.1deg
- Max. field
- F : 0.4T
- D : 0.065T
- tune
- h : 2.73
- v : 1.58



V per turn ~2-3 MV

Δp/p at injection = ± 20%

Δp/p at extraction = ± 2% (after 6 turns ~ 1.5 us)

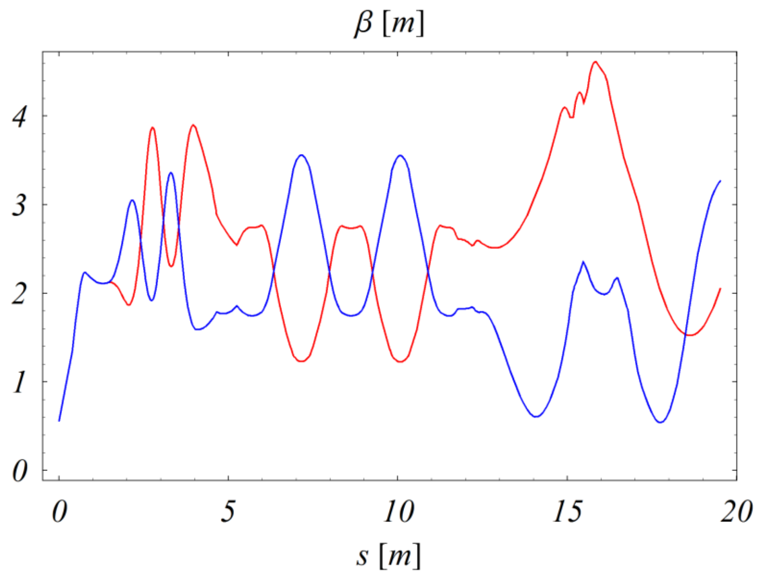
h=1

PRISM parameters

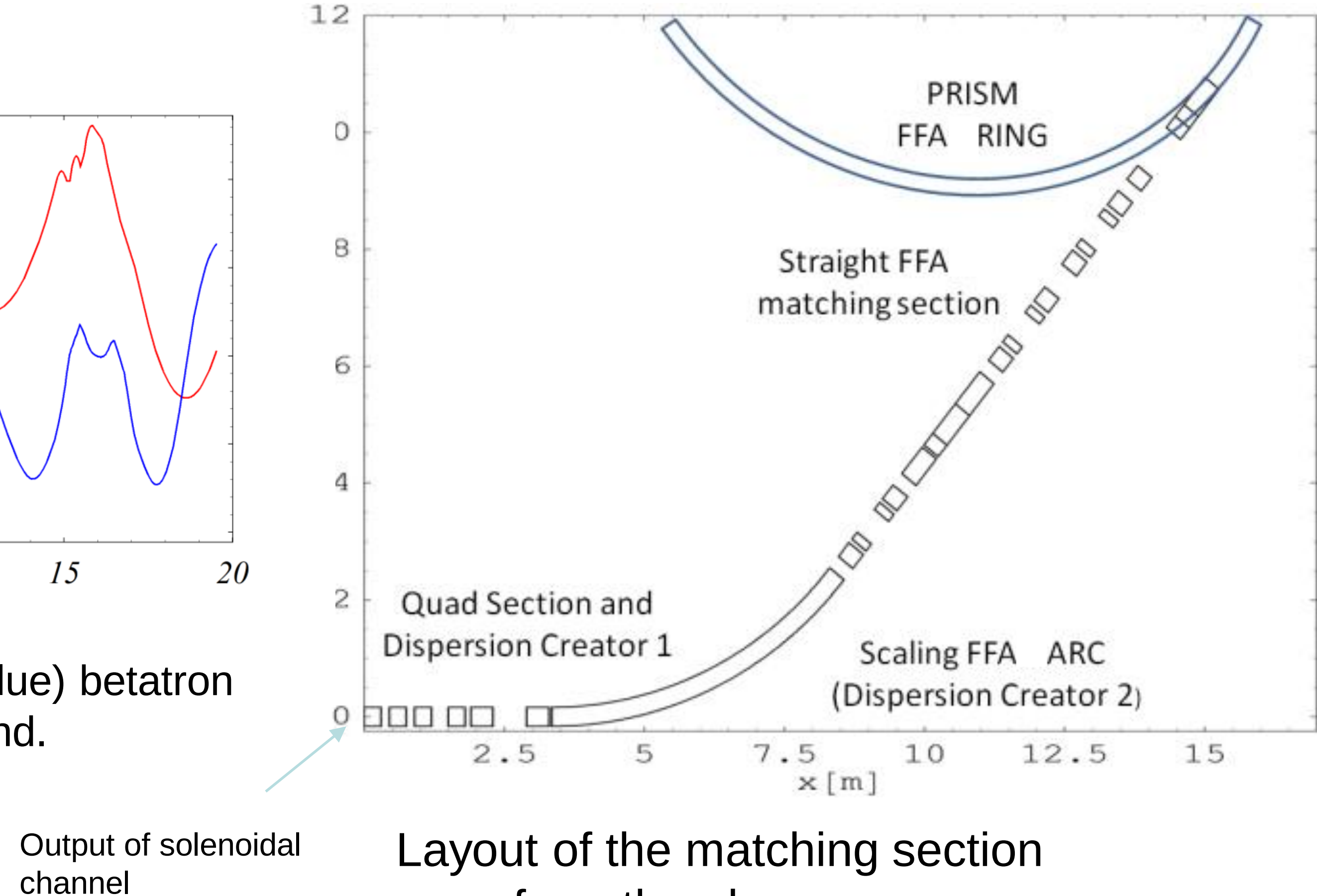
Parameter	Value
Target type	solid or liquid (powder)
Proton beam power	~1 MW
Proton beam energy	multi-GeV
Proton bunch duration	~10 ns total (in synergy with the NF)
Pion capture field	10 -20 T
Momentum acceptance	±20 %
Reference μ^-momentum	40-68 MeV/c
Harmonic number	1
Minimal acceptance (H/V)	3.8/0.5 π cm rad or more…
RF voltage per turn	3-5.5 MV
RF frequency	3-6 MHz
Final momentum spread	±2%
Repetition rate	100 Hz-1 kHz

Matching to the FFA

- A dedicated transport channel has been designed to match dispersions and betatron functions.

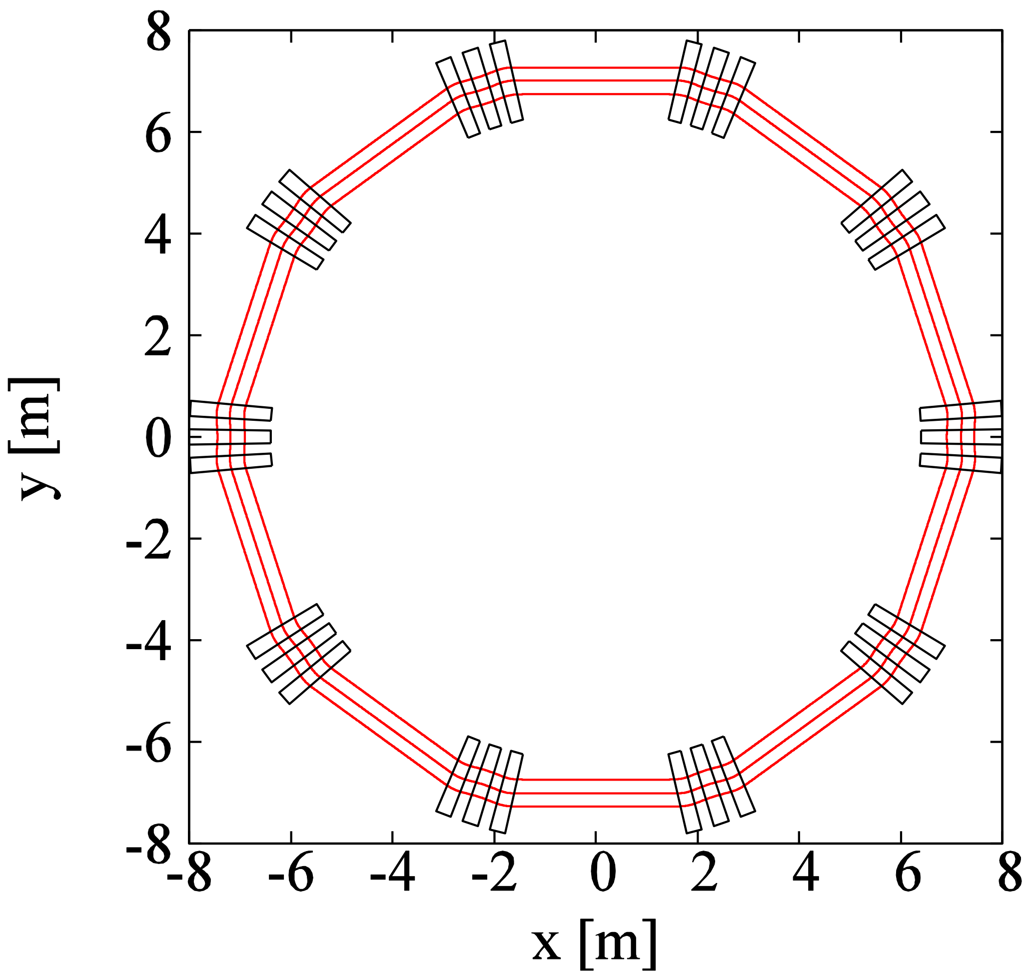


Horizontal (red) and vertical (blue) betatron functions in the PRISM front end.

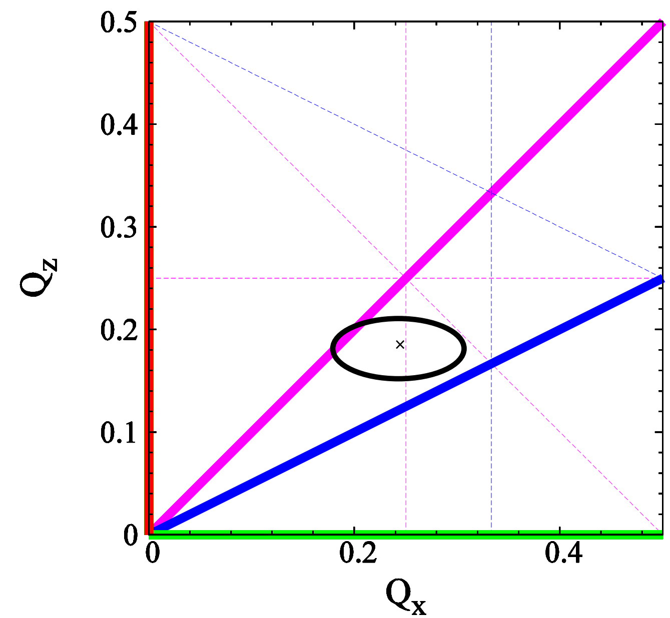


Layout of the matching section seen from the above.

New FDF scaling FFA design



- FDF symmetry motivated by the success of ERIT at KURRI
- 10 cells
- k 4.3
- R_0 7.3 m
- (Q_H, Q_V) (2.45, 1.85)
- Minimal drift length 3m



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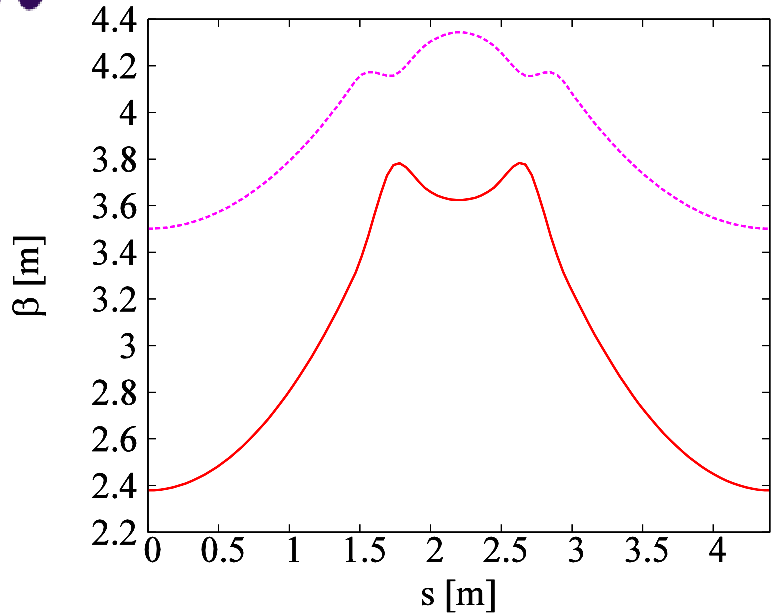
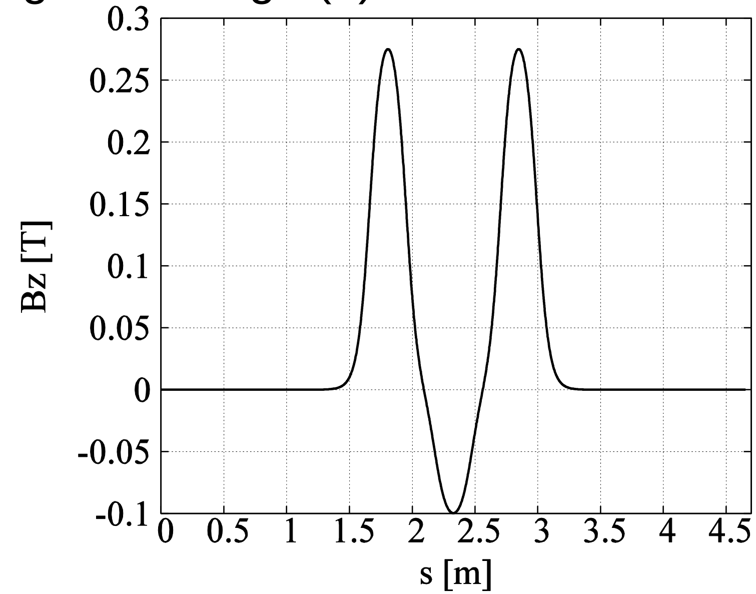
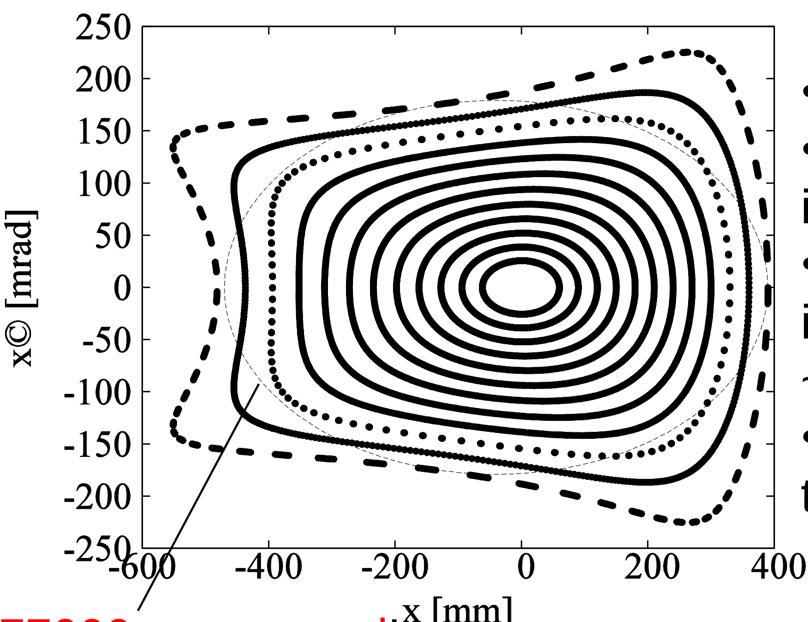
New FDF scaling FFA design (2)







77000 π.mm.mrad!

- Enge field fall-off used to study fringe fields
- Enormous horizontal acceptance is achieved in simulations
- Vertical long term stability of ~3000 π.mm.mrad is achieved, however with some optimization ~5000 π.mm.mrad should be stable for a few turns.
- 5000 π.mm.mrad is what we currently aim for due to injection limitations.

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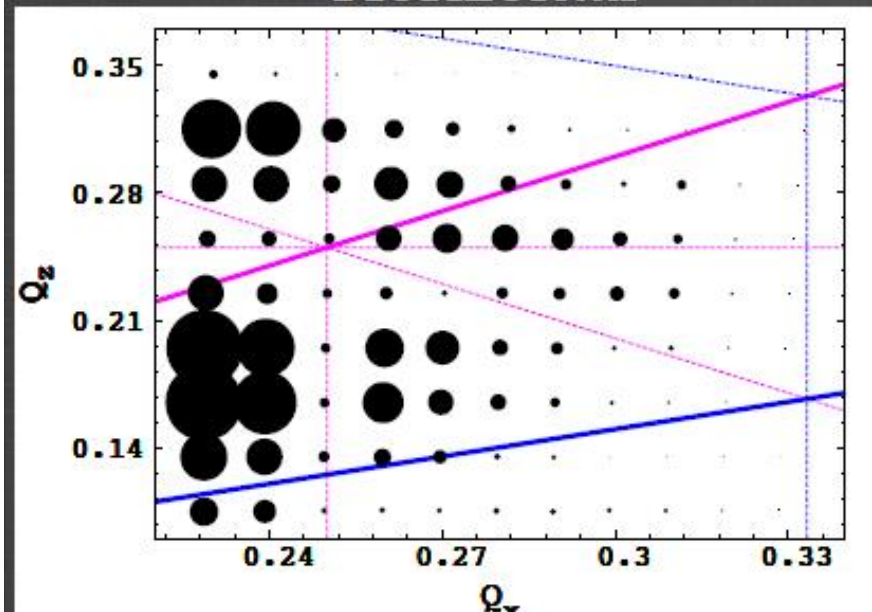
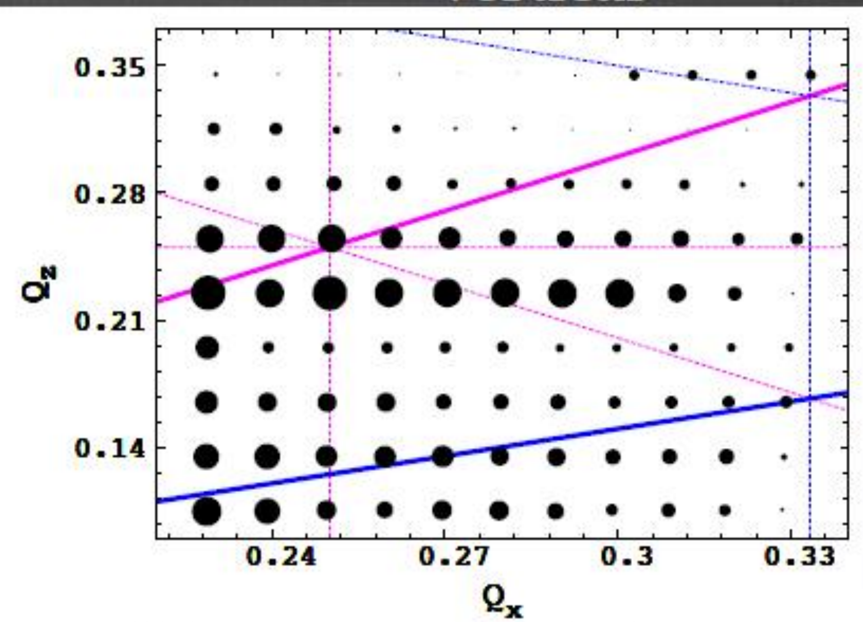
Study of DA for new design

10-cell FDF FFA

Horizontal



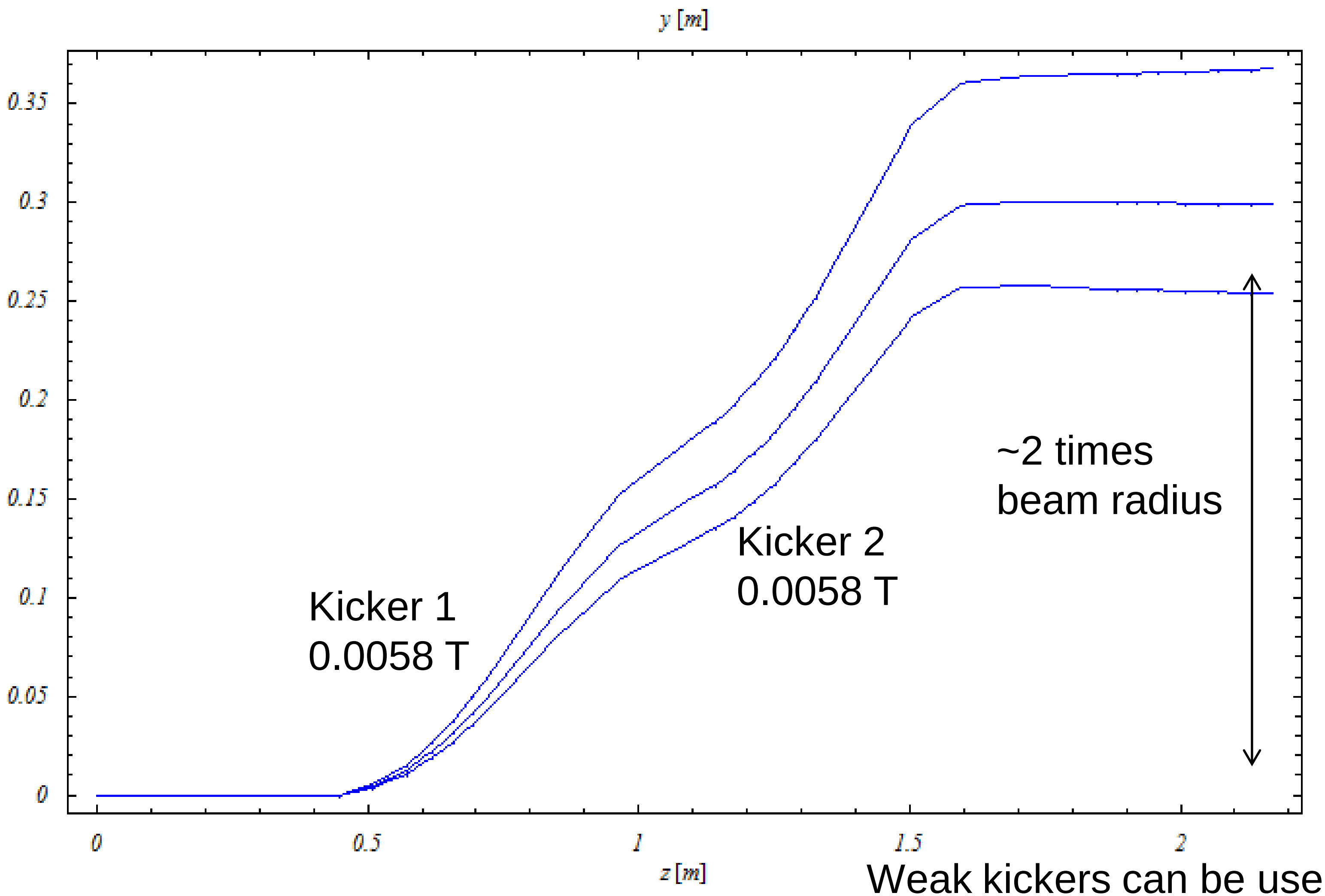
Vertical



>50 / >3 mm.mrad (H / V) achieved.

Vertical injection

Orbit separation with 2 kickers



Weak kickers can be used!

Conclusions

- We aim to make further progress on defining the PRISM system in the Snowmass paper

- We wish the Snowmass process will allow to endorse the PRISM system and to prepare the route for its funding

- Compressed bunches needed for PRISM can be generated using PIP-II linac and further upgrades of the FNAL chain or at J-PARC
    - We hope, further studies on generating the compressed bunches will be performed

- PRISM is a serious choice for the next generation cLFV experiment.